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A FURTHER STRATIGRAPHIC STUDY IN THE
MOUNT DIABLO RANGE OF CALIFORNIA

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CONTENTS

	PAGE
INTRODUCTION	2
CONDITIONS OF DEPOSITION DURING THE TERTIARY	6
THE CRETACEOUS AND EARLIER SERIES	8
THE EOCENE ROCKS	9
<i>Distribution</i>	9
<i>Stratigraphy</i>	11
<i>The Lower Sandstones</i>	12
<i>The Lower Shales</i>	13
<i>The Upper Sands</i>	14
<i>The Upper Shales</i>	15
THE MIOCENE SERIES	17
<i>The Temblor Beds</i>	18
<i>The Monterey Shales</i>	20
<i>The Coalinga Beds</i>	22
THE PLIOCENE SERIES	28
<i>The Etchegoin Beds</i>	28
<i>The Tulare Formation</i>	31
THE PLEISTOCENE RECORD	32
<i>The Terraces</i>	32
<i>The Pleistocene Deposits</i>	34
STRATIGRAPHIC RELATIONS	35
CORRELATIONS	37

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INTRODUCTION

When the earlier paper on this subject was published, under similar title, in 1905,¹ it was intended that it should be the first of a series of contributions to be offered at intervals as time and opportunity were afforded for the further study of the region. During its preparation it was not unforeseen that some of the details, or some of the applications of general conclusions, would subsequently require alteration or amendment, as exploration in the field should be extended farther and a more complete knowledge of the details should be acquired. With this in view it was nevertheless believed that such a contribution would be well worth while, even though corrections might be found necessary as the study progressed, since it would at least serve to stimulate investigation and thus tend to develop our knowledge of the subject. And this result has undoubtedly been attained.

Since the publication of the former paper, the attention of the U. S. Geological Survey has been directed to this field; and a systematic study of its stratigraphic and economic features has been begun, which will undoubtedly add much to our present knowledge.

During the two years and more since the publication of the earlier paper, exploration has been extended along both sides of the range for many miles beyond the portions that had then been covered, affording opportunity for more detailed work and for a better acquaintance with the stratigraphy and with the conditions under which deposition took place than was then possible.

Prior to, and after the publication of the former paper, large collections of fossils, chiefly marine invertebrates, had been made from all of the formations represented. As these had been stored in the Academy of Sciences, they were lost when it was burned in the great fire of San Francisco. In-

¹ Proc. Calif. Acad. Sci. 3d ser. Geol. v. 2, no. 2, pp. 156-248.

deed, at the time of the fire the present paper was in process of preparation and the manuscript was partly written; but on account of the destruction of the collections, its publication has not only been delayed, but in the form and matter of its contents it has been considerably altered and reduced.

The general statements made in the earlier paper concerning the stratigraphic sequence in the Mount Diablo range, have proved to be fairly correct, and the same may be said of the formal statement of conclusions. It is only in their application within a certain definite portion of the field (and this within the area covered by the map) that any amendment is required. However, under a combination of circumstances, such error was unavoidable: In the first place, the field had been approached from the south, which was a direction of several disadvantages; in the second place, little was known from the literature concerning the general stratigraphy of the Eocene, and supposed Oligocene of the West-coast, and less concerning the geologic range of certain species of invertebrates, such as *Pecten peckhami*, and certain species of *Tellina* and *Leda*, and of several forms in the later Neocene.

Since the former publication, however, some important additions have been made to the literature of the West-coast Tertiary, chiefly by Dr. Ralph Arnold¹ and by Geo. H. Eldridge and Arnold;² and the paleontology of the Tertiary formations of the West has been somewhat enlarged.

It is due also to remember certain observations made by Mr. J. S. Diller,³ presumably upon the authority of Dr. Dall, regarding the occurrence of *Pecten peckhami* in the supposed Oligocene deposits of northwestern Oregon. While it may remain to be proved that the entire series described by Mr. Diller is properly referable to the Oligocene, it is clear that below a great thickness of sandy strata which are probably lower Miocene, there is a still greater series of ashy clay shales

¹ Tert. and Quat. Pectens of Calif. U. S. Geol. Surv. Prof. paper 47, 1906.

² See discussion of the oil districts of southern California in Bulls. 309 and 321, U. S. Geol. Surv.

³ U. S. Geol. Surv. 17th Ann. Rept. pt. 1, pp. 464-469.

and sandstones with a very different fauna. Toward the top of this lower series the fauna includes:

<i>Dolium petrosum</i> CONRAD	<i>Scaphander</i>
<i>Nucula truncata</i> GABB	<i>Cylichna</i>
<i>Yoldia impressa</i> CONRAD	<i>Leda</i>
<i>Pseudomusium peckhami</i> GABB	<i>Tellina</i>
<i>Dentalium</i>	

And still lower in the conformable series was collected a fauna that was referred without a doubt to the Eocene, among which were the following:

<i>Heteroterma trochoidea</i> GABB (?)	<i>Pyrula tricostata</i> LAM.
<i>Rimella canalifera</i> GABB	<i>Aturia angustata</i> CONRAD
<i>Urosyca candata</i> GABB	

Mr. Diller adds: "Notwithstanding the presence of *Aturia*, which is a characteristic Oligocene form, Dr. Dall refers these fossils to the Eocene."

Writing later of the Oligocene in the United States, Dr. Dall¹ says: "In the southeastern United States there is no marked stratigraphic break between the Eocene and the Oligocene. Many of the fossils persist into the upper beds, but the fauna as a whole undergoes a well-marked alteration, showing that physical changes of some sort, such as would profoundly affect the fauna, must have taken place. The change by which the Oligocene was brought to a close and the typical Miocene inaugurated, caused, as already described, the most remarkable faunal break in the geological history of the United States after the Cretaceous."

The stratigraphic relations of undoubted Oligocene deposits in California have not been so clearly stated, though there are supposed Oligocene deposits on the southern coast that have been similarly described.

Dr. Ralph Arnold² has described Oligocene deposits from the Santa Cruz mountains lying below the lower Miocene with a fauna which he considers intermediate between typical Tejon and lower Miocene. This fauna includes *Pecten peckhami* and other forms not unknown in the Miocene of California.

¹ U. S. Geol. Surv. 18th Ann. Rept. pt. 2, p. 331.

² U. S. Geol. Surv. Prof. paper 47, pp. 16-17.

Geo. H. Eldridge and Arnold¹ have also described beds of transitional character, presumably Oligocene, as occurring in the Coast ranges of Ventura county, California. Eldridge and Watts² had considered this series, known as the Sespe formation, to be of Eocene age; but as Arnold found Miocene fossils in its fauna, it has been provisionally referred to the Oligocene.

It appears, therefore, that below the Miocene, and occupying an intermediate position between it and the Eocene, there occur in Washington, Oregon, and California, marine beds that have been provisionally referred to the Oligocene, and that appear to be conformably related to the Eocene deposits, but from which the Miocene is more or less separated by either a stratigraphic or a faunal break. In the following pages illustrations will be found in which similar relations appear, but in which the strata involved have not yet been proved to be of the Oligocene age.

It is the purpose of this second paper to present results that have been attained since the publication of the first, to amend it where necessary, and to supplement it by the addition of such new facts as have been gathered in the more extended study of the field. Furthermore, as the former paper has become all but inaccessible through the total destruction of the reserve stock of the publications of the California Academy of Sciences, it is thought worth while to embody its results, in an abbreviated and improved form, in a second publication.

It is not intended that this paper shall be complete either in its scope or in its treatment of the subject, but that it shall, at least, be suggestive of some of the many interesting features of the field, and of the various phases of geological study that find here abundant and excellent illustration.

One of the important factors to be considered and worked out in a stratigraphic study of any region is that of the conditions of deposition—that is, the physical geography of the time and the various influences that may have affected the

¹ U. S. Geol. Surv. Bull. 309, pp. 7-12.

² Calif. State Min. Bur. Bull. 11, pp. 25-26.

character and distribution of the sediments of which the strata are composed. In the Tertiary deposits of the Mount Diablo range, along its entire extent of nearly 300 miles, there is a great variation in the character and composition of the constituent rocks, presenting every variety from coarse detrital conglomerates to two or three forms of fine organic shales and limestones, and alternations of these that are possible only under conditions far from simple.

CONDITIONS OF DEPOSITION DURING THE TERTIARY

During the Tertiary periods, if not during the Cretaceous, the physical geography of western California differed widely from that of the present time. In the positions of many present centers of stratification, constituting the main summits of the Coast ranges which now rise with more or less regularity and continuity, there existed during and throughout the Tertiary, at least, only chains of continental islands grouped in similar alignment. These island masses were not unlike some that now exist about the borders of the Pacific ocean and on the coasts of Alaska and even of California. Among them were enclosed seas, or basins, with interconnecting channels through which the tides and ocean currents ran at will, thus forming an unusual variety of conditions which directly influenced the character and variety of the faunas of the time.

Among such basins were the Great valley, the Salinas, the Santa Maria-Carisa, and the San Fernando valleys. But for the present, without attempting to make a complete statement of either the Coast range waterways or island groups of the Tertiary, it is sufficient to note only the fact that along the course of the Mount Diablo range six or more centers, or stratigraphic cores, have been recognized and to some extent correctly described by Whitney as the natural divisions of the range. These centers were to some extent outlined in the former paper; they deserve far more attention than can be given here. But while Whitney correctly observed and noted these various divisions of the range, its double character and

other complex features have hitherto escaped attention. However, these points can not be taken up in the present paper.

Among the divisions enumerated by Whitney are the Panoche, the San Carlos, and the Estrella, which, he says, are individualized by certain low passes extending across the range. Considering these divisions as separate islands or groups, it would ultimately be necessary to subdivide some of them at least into two, or perhaps three sections for special epochs of the Tertiary, with waterways extending from the basin of the Great valley to that of the Salinas. One of these open channels lay along the course of the west branch of the Jacalitos and the upper Warthan creeks, and one along the Los Gatos creek and the San Benito river, thus dividing the San Carlos division into three sections or subdivisions for at least a part of the Tertiary. In a complete or detailed study of the range, other channels and the islands separated by them at one time or another would require notice, but those mentioned are perhaps sufficient to illustrate the nature of the problem.

In all probability, as time went on during the successive periods or epochs, certain geographical changes occurred which resulted in either increasing or decreasing the width and number of these transverse channels; and these results could have been accomplished by simple changes in elevation. It appears that during the Miocene period only the Warthan channel was open, while during the Pliocene both the Warthan and the Los Gatos channels were in existence, as is shown by the distribution of the Miocene and Pliocene sediments along them.

The islands and channels that existed during the Eocene can not be so easily discerned, but undoubtedly there were many.

Eocene sediments run well into the range, if not across it, on the borders of the Livermore and Panoche valleys; and the same is probably true in the neighborhood of the Antelope and the Cholame valleys, as well as farther south.

Probably this statement of the insular condition in Tertiary times is sufficient to illustrate some of the factors that affected

the character, quantity, and distribution of the various strata concerned in this discussion. It will readily be conceded that the sorting and transporting influence of ocean currents through channels and waterways can not be small, and that it is entirely adequate to explain many of the seeming irregularities, both lithological and faunal, that may appear later in the course of these studies. There are in some quarters rapid transitions in both the nature of the sediments and the character of the fauna as one follows the strata along their strike. Some important beds are known to entirely disappear or to change their character or appearance to such an extent that they can be recognized only by their stratigraphic position with respect to others that are better known. The later Miocene particularly appears to have been an epoch of rapid changes in these respects, but of changes that are explainable by sufficient attention to the details of physical geography.

THE CRETACEOUS AND EARLIER SERIES

It is not designed to give here any special account of the Cretaceous and earlier rocks of the range, although both are abundant about each of its older centers, as was illustrated in the former paper. The occurrences of Cretaceous and "metamorphic" rocks have been noted by Whitney¹ at Mount Diablo, Corral Hollow, and Panoche Pass, and have been followed by him as far to the south as the Panoche valley. Becker² and White have published lists of Chico species occurring at New Idria, and similar beds have been identified upon the tributaries of the Cantua and Salt creeks. Miss H. C. Lillis has collected from these beds the following species, which were left at the University of California:

<i>Baculites chicoënsis</i>	<i>Baculites</i> sp.
<i>Arca breweriana</i>	<i>Chione</i> sp.
<i>Dentalium stramineum</i>	<i>Perissolax</i> sp.
<i>Cinulia obliqua</i>	<i>Natica</i> sp.
<i>Gyrodès conradiana</i>	<i>Margarita</i> sp.

¹ Geol. Surv. Calif. Geol. v. 1, pp. 45, 55, etc.

² U. S. Geol. Surv. Monog. no. 13, pp. 291-309.

From Salt creek these Cretaceous rocks have been followed continuously to the Los Gatos, Warthan, Jacalitos, and Avenal creeks, and indeed to the Devil's Den, on the north side of the Antelope valley. It is quite probable that the tawny yellow sandstones occurring south of the Antelope valley are of Cretaceous age, but as yet no proof of it is at hand.

From the published lists of fossils occurring in the range it would appear that the Chico portion of the Cretaceous has been more often identified, though species of *Aucella* have proved the presence of the Knoxville at Mount Diablo (and Becker was convinced that some of the rocks at New Idria belong to the "Knoxville series"), while from the black shales on the Jacalitos creek species of *Hoplites* have been found, and at the Devil's Den both *Hoplites* and *Belemnites* were collected in similar dark shales.

It thus appears that both Knoxville and Chico strata enter into the composition of the range and are far more abundant upon the eastern flank than upon the western. The Cretaceous rocks always stand at a high angle, dipping away from the older formations and toward the valley at points of the compass varying according to their position. It is designed however that the structure of these and the younger series of formations shall be reserved to be dealt with later.

The so-called "metamorphic" rocks of the Mount Diablo range, occurring at intervals and in large areas, have generally included serpentines, trachytes, porphyries, and jaspers. The stratified portions are all representatives of the Franciscan series, while the eruptives include many of the classes usually found associated with them in the Coast ranges, among which are the products of local metamorphism of the most pronounced kinds.

THE EOCENE ROCKS

Distribution.—The Eocene rocks of the northern portion of the range have already had considerable mention by various writers, including Stanton,¹ Merriam,² Weaver,³ and others.

¹ U. S. Geol. Surv. 17th Ann. Rept. 1896, pp. 1009-1060.

² Journ. Geol. v. 5, no. 8, pp. 767-775.

³ Bull. Dept. Geol. Univ. Calif. v. 4, no. 5, pp. 101-123.

From the Straits of Carquinez they extend easterly, forming a well defined belt along the northern border of Mount Diablo, which can be followed as far eastward as Byron or Brentwood. Farther south the more important areas that have been noted are at Corral Hollow,¹ New Idria,² Coalinga,³ and southward.

While Eocene rocks have not been followed continuously along the range, it is perhaps due to lack of exploration rather than to their absence. From New Idria the Eocene can be followed westerly for an indefinite distance, while to the east and south it has been followed continuously to Coalinga. The following list of fossils was obtained by the writer at Corral Hollow, from a stratum a few hundred feet above the Eureka vein of the Tesla coal mine:

<i>Neverita secta</i> GABB	<i>Tellina longa</i> GABB
<i>Tritonium</i> sp. undet.	<i>Leda gabbi</i> CONRAD
<i>Turritella wasana</i> GABB	<i>Solen stantoni</i> WEAVER
<i>Dentalium cooperi</i> GABB	<i>Lucina (?) cretacea</i> GABB
<i>Amauropsis alveata</i> GABB	<i>Mactra</i> sp. undescr.
<i>Actæon</i> sp. undescr.	<i>Meretrix horni</i> GABB

On the south side of the canyon other Eocene species were obtained, and it is evident that most of the coal veins of this vicinity are in rocks of Eocene age.

H. W. Turner⁴ recognized the white sandstones occurring at New Idria as of Eocene age and reports the following species from De Los Reyes canyon:

<i>Ostrea idriaënsis</i> GABB	<i>Morio (Sconsia) tuberculatus</i> GABB
<i>Neverita globosa</i> GABB	<i>Amauropsis alveata</i> GABB
<i>Rimella canalifera</i> GABB	<i>Meretrix wasana</i> CONRAD
<i>Cylichna costata</i> GABB	<i>Turritella</i> , fragment

Within 50 feet of the coal vein occurring near by he obtained:

<i>Solen (Hypogella) diegoënsis</i> GABB	<i>Neverita</i> sp. undet.
	Small lamellibranchs

¹ Geol. Surv. Calif. Geol. v. 1, pp. 34 *et seq.*

² U. S. Geol. Surv. Monog. no. 13, pp. 291-309.

³ Proc. Calif. Acad. Sci. 3d ser. Geol. v. 2, no. 2, pp. 162 *et seq.*

⁴ Am. Geol. v. 14, pp. 92-96.

From other localities in the neighborhood, he adds :

<i>Cardium cooperi</i> GABB	<i>Lucina (?) cretacea</i> GABB
<i>Pecten interradiatus</i> GABB	<i>Mactra</i> sp. undet.
<i>Modiola ornata</i> GABB	

To the south and east of Coalinga a narrow belt of Eocene beds can be followed for a distance of more than 15 miles, extending from certain tributaries of the Jacalitos creek eastward to the vicinity of Dudley on the northern border of the Sunflower valley. These beds appear again near the Point of Rocks on the northern border of the Antelope valley, from which locality several Tejon forms have been obtained and listed. To the south of the Antelope valley the Eocene beds can be followed without difficulty as far as Temblor, if not farther toward the southern extremity of the range. They appear again crossing the canyon of the San Emidio and can be followed from there eastward to the Tejon ranch.

Among other characteristics of the Eocene rocks, at least on the eastern side of the range, is the presence of beds of lignitic coal, or in some cases of carbonaceous clays, particularly in places where the Eocene section is greatly reduced. Almost all the coal veins reported along the valley side of the range, and some on the opposite side, are in Eocene strata.

Like the Cretaceous, the Eocene rocks are in evidence to a far greater extent upon the eastern than upon the western slope of the range, though they are known upon both.

North of the Straits of Carquinez, the Eocene has been noted as far as Upper Lake, Lake county, though its continuation is not known to be complete.

Stratigraphy of the Eocene.—In the vicinity of Martinez, the Eocene strata have been divided into two groups, mainly upon the basis of their faunas, and have been classed accordingly as Martinez and Tejon. The older, or Martinez, portion has been made the subject of a special study by Dr. J. C. Merriam¹ and by Chas. E. Weaver,² while the Eocene series, as a whole, has been clearly separated from the Chico by Dr. T. W. Stanton.³

¹ Journ. Geol. v. 5, no. 8, pp. 767-774.

² Bull. Dept. Geol. Univ. Calif. v. 4, no. 5, pp. 101-123.

³ U. S. Geol. Surv. 17th Ann. Rept. pt. 1, pp. 1011-1049.

In the northern part of the range the rocks are generally covered by soil to an extent that renders the stratification more or less obscure; so that little attempt has been made toward a detailed statement of their lithological characters.

Mr. Weaver states that the Martinez beds, for the most part, consist of thick bedded sandstones containing large quantities of glauconitè, and that alternating with these are considerable beds of shale.

In the vicinity of Corral Hollow both sandstones and shales enter into the composition of the Eocene; but no systematic statement of the strata has yet been made, except such as is given by Whitney, who did not, however, differentiate the Chico from the Tejon.

The belt of Eocene rocks lying between the Panoche Pass and Coalinga probably offers the best exposures and affords the best opportunity for both general and detailed lithologic study, and possibly an equally good opportunity for a formal classification. Along the Cantua creek, and both to the east and the west, a thick series of conformable strata can be followed easily for many miles. The aggregate thickness of the series is not less than 6000 feet, and is probably more. This series is readily divisible into four horizons, as follows:

Upper shales, organic.....	1800 feet
Upper sandstones, fossiliferous	2500 "
Lower shales, brown clays, etc.....	1000 "
Lower sandstones, concretionary	1000 "

Toward the southeast the series becomes perceptibly thinner, until in the vicinity of Coalinga it narrows to a point and entirely disappears below the succeeding series of Miocene.

The Lower Sandstones.—The lower sandstones of the Eocene series have not been thoroughly studied, and fossils have not yet been found in them within this area; therefore their classification as Eocene is based upon other evidence than fauna. They consist of soft and crumbling sandstone with a few harder layers, some of which are calcareous and are in some places more or less concretionary. A good example of these lower concretionary sands is to be seen in the rocky hill immediately northwest of "Oil City", Coalinga field. These

lower sands can be followed from this point both north and south for several miles. They rest upon dark clay shales of Chico age, with which they show every evidence of unconformity. In the former paper, these beds were called, provisionally, the "Avenal Sandstones", although they had not been followed continuously from the wells at Avenal, from which their name was taken.

The Lower Shales.—The next member of the series is one of rather unique character among the formations of the Mount Diablo range, chiefly on account of its purple-brown color and topographic effect. The shales, though sometimes calcareous or sandy and frequently filled with organic remains, are, on the whole, predominately clays. The calcareous portions are usually white lenticular masses only a few feet in extent, containing a variety of Foraminifera. Besides the white calcareous lenses, there are usually many scattered nodules of barite, fragments of selenite, and often some layers of sandstone. In the western part of the Coalinga field a sandy layer was found to contain many characteristic Eocene forms and some that are peculiar to the Martinez division. Among the many remains of Foraminifera found in these shales, there are numerous tests of numuloid forms occurring either in the sandy layers or in the calcareous concretions. Some of the sandy layers also contain scattered granules resembling glauconite.

On one of the tributaries of Salt creek some of the sandy beds contain:

<i>Turritella pachecoënsis</i>	<i>Leda gabbi</i> CONRAD
STANTON	<i>Fusus</i> (cf. <i>F. aquilateralis</i> WEAVER)
<i>Cardium cooperi</i> GABB	<i>Cylichna costata</i> GABB, etc.

Though none of these species may be exclusively of Martinez age, yet all of them occur in that horizon, and their presence does not therefore conflict with such an assignment of the beds.

The topographic aspect of these shales is striking and renders them easy to follow along the flanks of the range. They are easily reduced by erosion and therefore occupy a succession of depressions within which the transverse drainage of the range converges into its larger streams. The scanty soil

resulting from their decomposition is usually adobe-like, and is favorable for the growth of stunted oaks and junipers, but for no other vegetation,—not even grass.

In the midst of a zone of hills which are destitute of trees, this belt of brown shales sprinkled with trees is not hard to follow. The shales are usually clay-like and brown on the surface, though in good exposures they show a variety of colors, some of them being either red, white, or greenish. It was this member that was called, for convenience, in the former paper, the "Kreyenhagen shales". In some places the beds become sandy toward the bottom, but this is not a constant feature throughout their extent along the range.

The Upper Sands.—The thickest member of the Eocene, at least where it is best exposed, along the Cantua creek in the vicinity of the Lillis ranch, is that which was formerly described as the "Domijeau sands". Its thickness was roughly estimated as 2500 feet, though it may be more. As far as observed, there is considerable uniformity in composition, though there are some harder layers of fossil-bearing rock at intervals. In general these sands are yellow in color, soft and crumbling, with a disposition to weather into steep scarps imperfectly exposing the edges of the strata, which are often concealed by loose and sliding soil.

Except in the harder fossiliferous beds and in some concretionary layers, the sands are but little consolidated. Their greatest development is to be seen along the Cantua and Salt creeks and southward in the vicinity of the Domengine ranch, whence the name. The thickness of these sands is variable, but it increases somewhat regularly toward the north. In the vicinity of "Oil City", north of Coalinga, the thickness has been given as not over 350 feet, and a little north of the Domengine ranch as 1200 feet, while along the Cantua, it is not less than 2500 feet. Farther west it appears to again diminish though it extends at least as far as New Idria.

The fossils so far collected in this horizon are typically Tejon, though some of the species are found in the Martinez. In the vicinity of "Oil City", a hard layer at the base of the yellow sands yielded:

<i>Turritella uvasana</i> GABB	<i>Trochosmilium</i> sp.
<i>Dentalium cooperi</i> GABB	Foraminifera, many sp.
<i>Cardium cooperi</i> GABB	Crustacea sp.
<i>Leda gabbi</i> CONRAD	

Higher in the same beds and a little farther south, W. L. Watts¹ has collected:

<i>Discohelix leana</i> GABB	<i>Ficopsis cooperi</i> GABB
<i>Turritella saffordi</i> GABB	<i>Tritonium californicum</i> GABB
<i>Turritella uvasana</i> GABB	<i>Pectunculus sagittatus</i> GABB

A few miles north of this locality and near the Domengine ranch a hard sandy layer has yielded:

<i>Meretrix horni</i> GABB	<i>Turritella uvasana</i> GABB
<i>Cardita venrififormis</i> GABB	<i>Amauropsis alveata</i> GABB
<i>Cardium cooperi</i> GABB	Foraminifera (numuloid forms)
<i>Pectunculus sagittatus</i> GABB	Crustacea, etc.
<i>Tellina horni</i> GABB	

Along the Cantua this member of the series becomes more shaly toward the top, and the transition toward the succeeding member is not sharp but gradual. Farther south thin hard beds of sandstone mark the basal portion of the overlying shales, but they diminish in frequency higher up.

Crystals and veinlets of selenite are abundant in many parts of this member.

The Upper Shales.—The uppermost member of the conformable series that is here referred to the Eocene is one consisting almost entirely of shales, but containing some thin sandy beds near the bottom. On the Cantua creek east of the Lillis ranch house these shales are well exposed on the slopes and in the ravines on the north side of the stream. There is a total thickness of nearly 1800 feet, including some of the thin sandy beds near the top of the preceding member. They are divisible locally upon the basis of color and lithology into:

White chalky shales	800 feet
Brown clays, etc.	1000 "

Their unconformity with the succeeding beds is apparent, both from the abrupt change from fine organic shales to coarse grained sands or even pebbly gravels, and from the fact that

¹ Bull. no. 3, Calif. State Min. Bur. pp. 62 *et seq.*

in some places an angular difference in strike and dip is plainly to be seen. Furthermore, as the formations are followed southward, the series with which these shales are identified finally disappears beneath the later series.

The upper shales do not maintain the thickness stated above as they are followed southward. In the vicinity of the Domenigine ranch, they are reduced to about 1000 feet, while at "Oil City" the thickness is not above 600 feet, and that of the entire Eocene series is only about 2500 feet. Farther south and west they entirely disappear in the western part of the Coalinga district.

The fauna of these shales consists of many forms of Foraminifera and marine diatoms, but with a scanty number of mollusks.

On the Cantua the upper white shales contain *Pecten peckhami* and many Foraminifera and diatoms. Near "Oil City" *Pecten peckhami* and other forms have been found by the writer and by W. L. Watts. Intermediate between these two localities, on Sec. 19, T. 18 S., R. 15 E., these white shales have furnished:

<i>Pecten peckhami</i> GABB	<i>Tellina congesta</i> (?) CONRAD
<i>Leda oregona</i> (?) SHUM.	<i>Callista</i> sp.

It was these upper brown and white shales which, on the basis of both their lithology and their molluscan fauna, were regarded as Miocene, and therefore as "Monterey shales", in the former paper. Had the succeeding Lower Miocene series been as fossiliferous, however, as new localities have since shown it to be, or had it been followed into the localities where the great unconformity is more evident, it would have been less easy to confuse these earlier shales with their counterparts in the Miocene.

As to the definite assignment of these shales to either the Eocene or the Oligocene in the time scale of California geology, that must be reserved for further study and for some future time. Stratigraphically and structurally they are certainly connected closely with the Tejon series, while faunally they are allied more closely to the Miocene.

In its structural features the Eocene is simple. It forms a monocline that dips away from the older rocks toward the Great valley with only such flexures in strike and dip as are consistent with the insular conditions of the period. The beds lie along the eastern and northern slopes of the range in such a manner as to be in general concentric with the Cretaceous, presenting in some places the appearance of conformity, but on the whole showing the strongest evidences of unconformity. This unconformity is evident, as the formations are followed along the range, not only in the physical character of the various beds and in their fauna, but also in the distribution of the Eocene and the Cretaceous and in their lack of conformity in detail in many places.

On the western slope of the range, the structure of both the Eocene and the Cretaceous is less simple, and both formations are also less in evidence. The large amount of faulting which has taken place has complicated and obscured the geology, and no clear statement can be made without much detailed work.

THE MIOCENE SERIES

Regarding the occurrence, stratigraphy, and distribution of the Miocene in the Mount Diablo range, a fairly good statement was given in the former paper, except as to a part of the territory north of Coalinga. Miocene rocks are co-extensive with the range and can be followed almost continuously throughout its entire length, particularly along its eastern flanks.

In the earlier paper the stratigraphic divisions of the range were considered to be :

- (c) Coalinga beds
- (b) Monterey shales
- (a) Temblor beds

These do not form an entirely conformable series, though in some places it is difficult, or even impossible, to draw the line sharply between the several members. The greatest degree

of conformity exists between the two lower members, and less between the others, as will be shown farther on.

The Temblor Beds.—Probably the most persistent member, after proper discriminations are made, is the lower, which is also the one best characterized by fossils, and is therefore the most easily recognized faunally. Its occurrence at the type locality has been already sufficiently described. It has also been noted at intervals along the eastern base of the range as far north as Coalinga. Northward of Coalinga the Temblor beds follow the range for an unknown distance, but certainly to the Cantua creek and to New Idria. They maintain a fairly uniform thickness and constant sequence of strata, though not always a constant fauna. Just north of the Cantua on the Lillis ranch, the following representative section was noted:

Neocene Strata	2000 feet
Temblor Beds	
(g) Thin calcareous beds with <i>Turritella ocoyana</i>	30 feet
(f) Clay shales with Foraminifera	150 "
(e) Loose gray sands	60 "
(d) Thin calcareous sand with <i>Turritella ocoyana</i>	8 "
(c) Loose friable sands	80 "
(b) Yellow sands with <i>Turritella ocoyana</i>	8 "
(a) Gray sands and gravels....	50 "
Hard calcareous bed with barnacles	5 "
Loose gray sands	100 "
Total .. —————	491 "
White shales with <i>Pecten peckhami</i> ..	800 "

Usually there are three layers of fossiliferous rock within the Temblor horizon, bearing typical Lower Miocene fossils such as the following:

- (a) Loose sands with *Pecten discus* CONRAD
Astrodapsis sp.
Barnacles, etc.

- (b) Yellow sands with *Mytilus mathewsoni* GABB
Ostrea titan CONRAD
Venus sp.
Zirphaea sp.
Pecten discus CONRAD
Pecten sp.
Chione sp.
Turritella ocoyana CONRAD
Agasoma sp.
Cancellaria sp.
Bulla sp.
Macoma sp.
Trochita filosa GABB
 Numerous small gasteropods
- (d) Thin white calcareous bed with *Chione tem-*
blorensis ANDERSON
Ostrea titan CONRAD
Dosinia sp.
Crepidula sp.
Agasoma kernianum COOPER
Turritella ocoyana CONRAD
Neverita callosa GABB
Trophon kernensis ANDERSON
Conus owenianus ANDERSON
Olivia californica ANDERSON

Above the beds classed as Temblor there is a gypsiferous clay shale 250 feet in thickness, overlain by 50 feet of coarse gravels and conglomerates.

From the Cantua creek the Temblor beds have been followed southeastward to the vicinity of the producing oil wells and to within a short distance of Coalinga and to the Jacalitos creek. A large part of the strata formerly placed in a succeeding group has been found to belong to the Lower Miocene. The "Reef Bed" of the former paper is properly a part of the Temblor, and has yielded, on Sec. 20:

<i>Hinnites</i> (rel. <i>H. giganteus</i>) GRAY	<i>Bulla</i> sp. <i>Trochita</i> sp.
<i>Mactra densata</i> CONRAD	<i>Hemifusus wilkesana</i> ANDERSON
<i>Metis alta</i> CONRAD	<i>Neverita callosa</i> GABB
<i>Pecten discus</i> CONRAD	<i>Astrodaopsis merriami</i> ANDERSON
<i>Arca montereyana</i> OSMONT	Teeth of sirenians (<i>Desmo-</i> <i>stylus</i> sp.)
<i>Dosinia ponderosa</i> GABB	
<i>Lucina borealis</i> LAM.	

At the base of the Temblor beds is a pebbly conglomerate that serves to give emphasis to the abrupt change from the fine organic white shales upon which they rest.

It is easy therefore to recognize the unconformity that exists between the Temblor beds and the white or brown shales provisionally classed as Oligocene. This unconformity is that formerly described as conspicuous between the Coalinga beds and the Monterey shales. The pebbles of the conglomerate include metamorphic schists, jaspers, porphyries, serpentine, sandstone, and even some rocks that appear to have come from the calcareous concretions of the preceding series.

The Temblor beds contain the principal oil-yielding strata of the Coalinga field, and are well constructed to do so, not only stratigraphically and structurally, but also on account of the porous and unconsolidated character of the larger sandy members. The usual thickness of the Temblor beds is from 450 to 550 feet. In drilling for oil it has been found that various horizons are productive, the oil ranging through almost the entire thickness, though locally it is generally confined to one or two productive strata. Although in some parts of the field oil has also been found in strata both above and below the Temblor, the latter may be regarded as the chief source of the oil in most cases north of McKittrick.

In the McKittrick district the Temblor beds are known to be oil-bearing, but farther south they do not form the principal productive horizon. They occur, however, on the San Emidio and at Kern river, at the base of thick series of sandstones which underlie petroliferous beds. It is perhaps due to a change in the character of the strata above the Temblor that they do not everywhere contain the principal deposits of petroleum.

The Monterey Shales.—To the north of the Temblor ranch house, in western Kern county, is a thick series of white shales overlying the Lower Miocene and containing *Pecten peckhami* near the top and bottom. Its total thickness has been estimated at more than 5000 feet. This series of white shales has been referred to the Monterey, and there can be no reasonable doubt that at least a large part of the formation should

be so classed. From this locality these shales can be followed with more or less continuity northward to the Devil's Den and to near Coalinga. The Monterey shales and the underlying Temblor beds, as they occur along the hills to the south and east of Coalinga, have already been described in the former paper. To the north of Jacalitos, if the Monterey shales occur at all, they are in extremely reduced thickness or in modified form.

In the eastern part of the Coalinga field, certain beds occupying the stratigraphic position of the Monterey, have a thickness of only 250 to 300 feet. In their outcrop along the hills in the northern part of the field, they are variously colored, white, yellow, or red, and have at most points a decidedly sandy appearance. The "Red Hills" to the north of the property of the "California Oil Fields, Ltd." form an exposure that is conspicuous on account of its brick-red color. This can be easily followed northward to the Cantua creek and beyond, though its color is not persistent. This member of the Miocene was, in the former paper, described as "a yellow sand" and included with the Coalinga beds. In the wells drilled in the eastern part of the field this member appears as a bluish sandy shale which is commonly called the "Big Blue". The buff, yellow, or red color seen in the outcrops is probably due to the oxide of iron derived from the decomposition of certain iron-bearing minerals. With a good lens grains of serpentine and other talcous minerals can be detected in these shales. Their separation from the Temblor beds in the field to the north of Coalinga is for convenience in logical treatment rather than for emphasis of their stratigraphic prominence.

To the north of the Cantua creek these shales are even more sandy than farther to the south. It is not unlikely that there is a gradual thinning out of the Monterey shales from the Temblor valley northward to the Cantua creek, but this can not now be affirmed. South of the Temblor valley a vast series of white shale follows the range as far as Sunset and then swings eastward toward the San Emidio, becoming more and more sandy toward the east. No direct evidence is at

hand to establish its position in the stratigraphic scale, but it is supposed to be the continuation of the Monterey shales occurring north of Temblor. In the range west of Midway and to the south of Sunset they have an aggregate thickness of nearly 5000 feet and contain the usual lithologic peculiarities of the Monterey. As the Temblor beds are known to occur at San Emidio, there is a presumption in favor of these shales being properly the Monterey. To the south of the Temblor valley the structure of the Miocene rocks is that of a high anticlinal fold along the axis of the range, with a steep dip toward the Carisa valley and, near Sunset, toward the south. This anticline disappears in the vicinity of the San Emidio canyon.

The Coalinga Beds.—The uppermost member of the Miocene series is best characterized and most easily followed along the base of the hills north of Coalinga, but it attains its greatest stratigraphic development to the south and east of the Warthan creek. In the former paper, on account of its thickness and more varied fauna in the Warthan creek localities, it was made to include more strata farther north than should have been included. It is now proposed to restrict the name Coalinga beds to the lower portion of a series that is unconformably related to the older members of the Miocene. In the vicinity of Coalinga there are two somewhat different types of this formation occurring in the localities mentioned. As here restricted, the Coalinga beds contain from 500 to 800 feet of strata at the north—that is, between Coalinga and the Cantua creek, and from 1000 to 1500 feet in the field between the Warthan creek and Tulare lake.

These differences are due primarily to the conditions of deposition during the latter part of the Miocene period. Along the hills north of Coalinga this series begins with a basal conglomerate varying in thickness from 15 to 50 feet or more, and consisting of coarse pebbles and boulders often ranging in weight up to several hundred pounds. At Salt creek and northward to the Cantua, the weathering and faulting of this conglomerate has produced the effect of enormous thickness, which is deceptive. In many places, as north of the Cantua,

this basal conglomerate can be recognized and followed where other strata of the Coalinga beds can not be so easily identified. Above the conglomerate are thick beds of gigantic oysters, pectens, and barnacles that form a conspicuous feature of the formation. Usually there are two or more beds of shells from 6 to 20 feet thick included with 100 feet or more of sands. In Sec. 10, T. 19 S., R. 15 E., the oysters occur in four beds extending through nearly 200 feet of sandy strata. The shells are usually firmly cemented together and weather into a bold escarpment in which little else than huge oysters is to be seen. These beds of fossils in which oysters are the most abundant are often used in tracing the oil-bearing strata of the Temblor through parts of the field in which the latter do not show plainly on the surface. The species that characterize these beds include:

<i>Ostrea titan</i> CONRAD	<i>Chorus carisaënsis</i> ANDERSON
<i>Pecten crassicardo</i> CONRAD	<i>Chione temblorensis</i> ANDERSON
<i>Pecten estrellanus</i> CONRAD	<i>Astrodapsis tumidus</i> REMOND
<i>Pecten</i> (rel. <i>P. islandicus</i> MULL.)	<i>Astrodapsis</i> sp.

The basal conglomerates and the oyster beds with which they are associated overlie the red or variously colored shales described in the preceding section. There is little or no angular unconformity between the shales and conglomerates, though the abrupt change in the fauna and in the character of the deposits testifies to a change of considerable importance in the physical geography of the time.

A short distance above the highest oyster bed is a layer of sandy white shale 80 feet in thickness, and a sandy stratum immediately overlying the shale on the west side of Sec. 20, T. 18 S., R. 15 E. has furnished the following species:

<i>Cytherea (callista)</i> sp.	<i>Diplodonta harfordi</i> ANDERSON
<i>Chione temblorensis</i> ANDERSON	<i>Agasoma kernianum</i> COOPER
<i>Macoma nasuta</i> COOPER	<i>Turritella</i> sp.
<i>Pecten estrellanus</i> CONRAD	<i>Cancellaria</i> sp.
<i>Zirphæa dentata</i> GABB	<i>Solen</i> sp.
<i>Lucina borealis</i> LAM.	<i>Trophon</i> sp.

The faunas of the foregoing lists are generally characteristic of the Coalinga beds. Above these fossiliferous beds the formation is chiefly sand with little or no appearance of fossils.

To the south of Coalinga, or of the Warthan creek, the conglomerates and the associated oyster beds do not form a conspicuous feature of the formation, and in fact have not been directly identified. This is probably due to the fact that these beds were greatly thickened by the addition of sands during the time that an open channel connected them with the sea to the westward, causing conditions not favorable to the life and growth of oysters, but favorable to the development of some species not often met with elsewhere.

Along the Jacalitos creek the thickness of the Coalinga beds has been estimated at 1100 feet. There is an appearance of unconformity between the Coalinga beds and those above, while the line separating them from the beds below is not definitely established. Along the various branches of the Zapato Chino creek and eastward the Coalinga beds thicken still more until they attain an aggregate of 1500 to 1600 feet. They rest upon the white or rusty brown beds of the Monterey shales, with which there is little to mark an unconformity. As the Monterey shales here become sandy in their upper portion, the change from them to the Coalinga is not so abrupt as in the field farther north. There is not a great variation of lithological characters in the Coalinga as seen along the range south and east of the Warthan creek. There is, however, near the middle of the series, a bed of white volcanic ash from 12 to 16 feet thick, which is in some places conspicuous, but which is not always found, or at least is not always recognizable. It can easily be followed for three or more miles southward from the Warthan creek, a little east of Alcalde, and it appears again on the west fork of the Jacalitos at the Roberts ranch and also on the eastern tributaries of the Zapato Chino, on the Kreyenhagen ranch. Near Alcalde it is immediately underlain by a fossiliferous bed from which the following species have been obtained:

<i>Pecten crassicardo</i> CONRAD	<i>Trophon</i> (rel. <i>T. ponderosum</i> GABB)
<i>Pecten estrellanus</i> CONRAD	
<i>Chione</i> (rel. <i>temblorensis</i> ANDERSON)	<i>Turritella</i> sp.
<i>Mactra</i> (<i>Spisula</i>) <i>catilliformis</i> DALL	<i>Natica</i> sp.
<i>Mytilus mathewsoni</i> GABB	<i>Surcula</i> sp.
<i>Agasoma kernianum</i> COOPER	<i>Volutilithes</i> sp.
	<i>Ficus pyriformis</i> GABB (?)
	<i>Tamiosoma gregaria</i> CONRAD

The same bed some miles to the east upon the Kreyenhagen ranch contained, in addition to several of the preceding forms, the following:

<i>Glycimeris generosa</i> GOULD	<i>Scutella gibbsi</i> REMOND
<i>Cardium</i> , (cf. <i>C. quadrigenarium</i> CONRAD)	<i>Trophon</i> sp.
	<i>Natica</i> sp.

The forms most characteristic of the Coalinga beds in this part of the field are *Agasoma kernianum*, *Scutella gibbsi*, two species each of *Astrodapsis* and *Trophon*, and a *Chione*. These forms range through about 400 to 500 feet of sandy strata. Near the top of this zone there is often an abundance of *Ostrea attwoodi* and *Scutella gibbsi*.

The general and to some extent the specific resemblances of this fauna to that of the Temblor beds is of course evident; but a study of the strata above and below this horizon warrants the classification here proposed. The Miocene aspect of the fauna is unmistakable in the presence of such forms as *Agasoma kernianum*, *Chione temblorensis*, and the large species of *Cardium*, *Volutilithes*, etc.

A few hundred feet above these beds are the typical beds of the succeeding series, while below them are the Monterey shales and the typical Temblor.

The Coalinga beds have not as yet been followed continuously southward along the range beyond the Sunflower valley, though doubtless the task would not be impossible. They have not even been clearly recognized between the Sunflower valley and McKittrick. They form, however, a well defined and easily followed belt along the foothills west of the Midway district and to the south of Sunset. Northward this belt can be followed to a point a few miles north of Crocker Springs (Sec. 6, T. 31 S., R. 22 E.), and from thence it has been only

indirectly traced into the McKittrick district. West of the Midway district the Coalinga beds occur on both sides of the range, on the one side dipping toward the Great valley and passing below the Midway wells, and on the other side dipping to the southwest and under the Carisa and Elkhorn valleys. Their structure at this point is that of a denuded anticline, though it is not likely that the two slopes were ever quite horizontal. The thickness of these beds on both sides of the range is very great,—hardly less than 4500 feet.

Near their base they contain very coarse conglomerates and sandstones, among which may be found the characteristic fossils. The conglomerates often contain boulders of granite of immense size, some of them weighing 15 to 20 tons. The conglomerates at the base of the series range through several hundred feet of strata, of which they make up a large percentage. The species thus far found in these beds are those typical of the Coalinga, and include forms not found elsewhere in great numbers. They are more abundant on the western than on the opposite side of the range, though they have also been found on the eastern side. On the western slope near the locality commonly known as "the Dome", the following species have been found:

<i>Pecten crassicardo</i> CONRAD	<i>Tamiosoma gregaria</i> CONRAD
<i>Pecten estrellanus</i> CONRAD	<i>Chorus carisaënsis</i> ANDERSON
<i>Ostrea titan</i> CONRAD	

These beds have been followed northward along the western side of the range to the neighborhood of Simler. They pass in a synclinal fold below the Carisa valley and appear again on its western border. Near La Panza Springs an identical fauna has been obtained with the addition of such typical forms as:

<i>Chione temblorensis</i> ANDERSON	<i>Lucina borealis</i> LAM.
<i>Trophon</i> sp.	<i>Astrodapsis tumidus</i> REMOND
<i>Turritella</i> sp.	<i>Astrodapsis whitneyi</i> REMOND

and many other species. Not far away, at the crossing of the San Juan creek, these beds overlies an immense thickness of Miocene strata including both the Monterey shales and the Temblor beds. In the foothills of the Midway district this

series contains above the basal conglomerates a great thickness of clays and shales, some of which are diatomaceous and chalklike in their physical appearance.

The wells drilled for oil in the Midway and Sunset districts, although they probably derive their oil from this series of strata, do not penetrate to the basal sands for their productive horizon. In fact the better wells so far drilled have been less than 2000 feet in depth, and some of the oil has been found in strata not altogether sandy. Near Sunset the oil sands often outcrop in unmistakable exposures, sometimes showing well defined beds of bituminous sand, 30 to 60 feet or more in thickness. Near the refinery of the "Sunet Oil Company" a layer of hard sand immediately overlying such an exposure contains:

<i>Crytomya californica</i> CONRAD	<i>Solen</i> sp.
<i>Tapes stanleyi</i> GABB	<i>Macoma</i> sp.

Some miles farther to the east on Lobos and Muddy creeks the same formation has yielded, according to W. L. Watts¹:

<i>Crassatella collina</i> CONRAD	<i>Tapes stanleyi</i> GABB
<i>Glycimeris generosa</i> GOULD	<i>Crytomya californica</i> CONRAD
<i>Macoma secta</i> CONRAD	<i>Macoma</i> sp.
<i>Neverita recluziana</i> PET.	<i>Tapes</i> sp.
<i>Dosinia mathewsoni</i> GABB	

As this locality has also yielded *Pseudocardium gabbi* Remond, it is likely that the *Crassatella* given in the above list is identical with this species, since the forms are somewhat alike.

These beds in the Sunset and Midway districts overlie the immense series of white shales described in the preceding pages as Monterey, and the evidences of unconformity are all that could be asked for. Not only are there abrupt and great lithological changes, as well as a change in faunas, but an angular difference in dip and strike is clearly seen at many points along the range. From an examination of the lists here given and of the facts herewith presented, it will be seen that the Coalinga beds have been clearly identified in the foothills about the southern end of the Great valley, and this identification can be confirmed by many other facts that are not here presented.

¹ Bull. no. 3, Calif. State Min. Bur. pp. 38 and 40.

In their general features, faunal and other, the Coalinga beds resemble the San Pablo beds to some extent; and it is not impossible that in part the two may be equivalent, though, as will be shown later, it is hardly probable.

THE PLIOCENE SERIES

The Etchegoin Beds.—It is quite possible in many parts of the Mount Diablo range to recognize a marine series later than, if not always distinct from, all of the preceding. This is the series called in the former paper the "Etchegoin Beds". It must be admitted that no sharply defined line separates this series from that last described, though evidence is not lacking of a change in the physical conditions of their deposition.

Generally the strata of the Etchegoin beds are conformable in position with those of the Coalinga, and there is no great change in the lithology, such as is seen in some of the earlier formations. One of the most conspicuous characteristics of the later series is an enormous amount of bluish gray sand which is distributed throughout almost its entire length and thickness. In this feature these beds contrast strongly with the yellow or light brown sands of the Coalinga and earlier series. From its fauna it may be more easily recognized within limits, though there are species that continue upward from the Coalinga, and as yet there are not many species that individually are to be regarded as a sure sign of the Pliocene throughout the Coast or even the State. The exact thickness of the Etchegoin beds has not been measured at any point, though it has been estimated at a few places. West of the town of Coalinga it is hardly less than 1400 feet in the outcrop, but in some of the wells drilled along the base of the hills it must be somewhat less. Farther north, near the eastern part of the field, the thickness is greater, as seen both in the outcrop and in the wells, where the aggregate is not less than 2500 feet, and may be more. North of the Avenal wells, 15 miles southeast of Coalinga, the thickness is probably as great as 3500 or even 4000 feet. Bluish gray sands usually make

up as much as 20 percent of the aggregate thickness, to which their peculiar color and slightly greater induration give an exaggerated effect. The strata are essentially sandy throughout, though clays are abundant in their upper portion, especially north of Coalinga and in the vicinity of Salt creek and the Cantua. In the former paper the Etchegoin beds were divided into two portions called respectively, the "Etchegoin Sands" and the "San Joaquin Clays."

The sands of this series are commonly coarse in texture and often pebbly, forming beds of conglomerate. Many of the pebbles and sand grains are jet black in color, and mingled with these is a kaolin-like matter, perhaps a decomposition product from volcanic ash. The gray-blue color which is so noticeable in these beds may be due to these ingredients and to their manner of mixture. This color has not been noticed in either of the other series and has generally been found to be a safe index to the identity of the Etchegoin beds. It has been noticed not only in the Coalinga field, but at McKittrick, near Buena Vista lake, at Mount Diablo, and on San Pablo bay.

One or two fossil horizons are to be recognized in the Etchegoin beds,—one near their bottom and another some distance above; but whether these are persistent or not cannot be stated. The most clearly defined and best characterized horizon includes some 400 feet of strata in which there are sometimes several separate beds of fossils. This horizon occurs near the bottom of the series and, as seen in the outcrops in the hills west and southwest of Coalinga, contains the following:

(n)	Brown sands with fossils.....	15	feet
(m)	Clay shales	40	"
(l)	Sandstone with fossils	10	"
(k)	Bluish gray sands	35	"
Lower fossil horizon			
(j)	Gray sands, gravels, and clays	65	"
(i)	Sandstone with fossils	10	"
(h)	Sands and sandy clays	80	"
(g)	Bluish gray sands	40	"
(f)	Argillaceous sand	100	"
(e)	Bluish gray sands	30	"
(d)	Sandstone with fossils	8	"

Near the middle of this zone a fossiliferous sandstone (bed i) has yielded the following species:

<i>Arca trilineata</i> CONRAD	<i>Saxidomus aratus</i> GOULD
<i>Metis (Lutricola) alta</i> CONRAD	<i>Glycimeris generosa</i> GOULD
<i>Mactra (Spisula) catilliformis</i> CONRAD	<i>Diplodonta harfordi</i> ANDERSON
<i>Pectunculus septentrionalis</i> MIDD.	<i>Tapes stanleyi</i> GABB
<i>Pecten oweni</i> ARNOLD	<i>Mytilus mathewsoni</i> GABB
<i>Pecten estrellanus</i> CONRAD	<i>Macoma inquinata</i> (?) DESH.
<i>Pecten crasscardo</i> CONRAD	<i>Nassa californica</i> CONRAD
<i>Ostrea titan</i> (?) CONRAD	<i>Natica lewisi</i> GOULD
	<i>Trochita costellata</i> (?) CONRAD
	<i>Scutella gibbsi</i> REMOND

In this horizon *Pectunculus* often occurs in great numbers, forming the dominant species. More than any other species it is persistent throughout the Coalinga field and is a survivor from the preceding series, in which it occurs in limited numbers.

The same fauna is found near the bottom of the Etchegoin sands along the tributaries of the Jacalitos creek and the streams farther east. It is everywhere characterized by the great abundance of *Pectunculus* and by *Pecten oweni*, *Scutella*, *Saxidomus*, and *Tapes*, by many other modern forms and by some living ones. Higher in the series the number and variety of *Pecten* species increase, and others which are abundant in the lower beds almost or quite disappear.

On the Zapato Chino creek and eastward a fossiliferous bed 1000 feet or more above the base of the series contains the following species:

<i>Arca trilineata</i> CONRAD	<i>Balanus</i> sp.
<i>Saxidomus aratus</i> GOULD	<i>Neverita reclusiana</i> DESH.
<i>Pecten coalingaënsis</i> ARNOLD	<i>Nassa californica</i> CONRAD
<i>Pecten wattsi</i> ARNOLD	<i>Terebratella</i> sp.
<i>Pecten etchegoini</i> ANDERSON	<i>Clypeaster (Scutella) brewerianus</i> REMOND
<i>Chama</i> sp.	<i>Clypeaster (Scutella) gibbsi</i>
<i>Ostrea</i> sp.	REMOND
<i>Tellina</i> sp.	Sharks' teeth, etc.

A comparison of these lists with the lists of the Pliocene occurring at Kirker's Pass, published by Whitney¹ and others,

¹ Geol. Surv. Calif. Geol. v. 1, p. 32.

makes it evident that in fauna the beds are alike, if not in part identical.

The clays at the top of the Etchegoin series to the north of Coalinga constitute at least a third of their entire thickness, or about 1500 feet. They have a somewhat banded appearance, the different strata showing different zones of color. Thus far no fossils have been found in them north of the Warthan creek, though elsewhere they have yielded *Scutella gibbsi* and the teeth of sharks.

The Tulare Formation.—In the former paper the Tulare formation was described as a series of fresh-water deposits outcropping on the borders of the Great valley and overlying all the earlier deposits occurring along the range.

It is found in the vicinity of Coalinga, in the Kettleman hills, and southward along the western side of the valley as far as McKittrick, Buena Vista lake, and about the Tejon ranch. The fresh-water mollusks forming the fauna of these beds in the Kettleman hills and near McKittrick have been noted by W. L. Watts¹ as identified by Dr. J. G. Cooper. Shells of the fresh-water mollusks, *Anodonta* and *Goniobasis*, have since been taken from a prospect well drilled one-half mile north of McKittrick. They occurred in a layer of hard sandstone at a depth of 1000 feet from the surface. After penetrating this layer a strong flow of gas threw sand and stones from the well with great violence and with them many shells and fragments of these species.

The beds of the Tulare formation are described as having a thickness of 1000 feet and standing at an angle of 30° and more in conformity with the underlying marine Pliocene. In the former paper they were tentatively correlated with the Orindan and associated beds described by Dr. Lawson from the Berkeley hills.

While a complete statement of its equivalents can not be given here, it is important to remark that the Tulare formation should have its continuation not only throughout the Great valley, but that its counterparts should occur in all the

¹ Bull. Calif. State Min. Bur. no. 3, 1894, pp. 49 and 53.

neighboring and intermontane valleys of the state. It is not improbable that the equivalents of the Tulare will be found to include the thick delta deposits of the San Benito and Salinas valleys described by Dr. Lawson¹ and later by Dr. H. W. Fairbanks.² If this correlation is correct, then according to Dr. Lawson they should also include the marine beds of the Merced series, which are generally regarded as of late Pliocene age. The Tulare formation should also have its equivalents among fresh-water deposits of the Great Basin region, but a discussion of this topic can not be undertaken here. Undoubtedly there is a close relation between these deposits and the Pleistocene deposits and terraces described below. Just what that relation may be can not now be stated with certainty, but probably the time interval was short between the close of the Tulare epoch and the opening of the Pleistocene.

THE PLEISTOCENE RECORD

The evidences of the Pleistocene period in the Mount Diablo range are confined to the foothills and the marginal plains of the Great valley. As far as known, there are no stratified beds distinct from those of the Tulare formation appearing along the range that could be classed as Pleistocene, though there are abundant evidences that the period, at least in part, was one of submergence if not of inundation.

The Terraces.—Along the flanks of the range upon both sides, and about the southern end of the Kern valley, there are many elevated terraces and other remnants of ancient plains that must have circumvented the Great valley. These elevated terraces and mesas are not all of uniform height, and this fact may be taken as an evidence of a series, rather than of a single plain of base-leveling, though in some places the variations of level are only those of a somewhat varied topography rather than those of an absolute plain. These terraces may be seen to advantage about the lower Kern river, the

¹ Bull. Dept. Geol. Univ. Calif. v. 1, p. 153.

² Jour. Geol. v. 6, pp. 551-576; U. S. Geol. Surv. San Luis folio, pp. 11-12.

Tejon ranch, Sunset, McKittrick, Coalinga, the Cantua creek, Tesla, and Mount Diablo. Their elevation varies between 1200 and 1500 feet above the sea, or between 850 and 1000 feet or more above the floor of the Great valley. On the western side of the range their elevation is perhaps a little less, and there is also a greater variation throughout and a considerably greater extent, particularly about the head of the Salinas valley drainage. Along the foothills on either side of the range it is not unusual to see these terraces rising from 200 to 400 feet or more above the beds of the various stream valleys. These terraces are well exhibited in the lower hills in the vicinity of McKittrick, Midway, and the Kern river. Most of the oil wells of the McKittrick district are drilled upon the outer border of a large section of such a plain. Similar remnants and other evidences of base-leveling are plainly marked along the foothills about the southern end of the valley, especially in the neighborhood of the Tejon ranch, where a careful study would probably reveal a series of different levels. At the mouth of Grapevine canyon a terrace is cut at an elevation of 600 feet above the floor of the valley.

In the vicinity of Coalinga the terraces are well marked in many places both north and south, but especially in the foothills to the east of Alcalde and still further eastward in the Kettleman hills. Not only are these marginal remnants of the old base levels to be seen as terraces along the slopes of the higher range, but in many places in the outlying hills there are mesa-like ridges and flats strewn with the usual deposits of alluvial debris.

The base-leveling here described has acted upon and truncated each and all of the stratigraphic series of the range, but naturally its effects have been most pronounced upon the younger and softer strata. In the foothills along the southwest border of the valley the denudation has beveled and truncated the upturned edges of all of the sedimentary series from the earliest to the latest, including the Etchegoin and even the Tulare beds. To a less extent it has acted upon the older series, but usually their greater hardness has protected them from the destructive effects of denudation.

As to the exact period to which these results of base-leveling are to be attributed it is not easy to say with certainty. While presumably the greater part of it was accomplished during the Pleistocene, part has undoubtedly been the result of Pliocene denudation, and part has occurred later.

Whitney¹ has classed the buried river channels of the Sierra Nevada as belonging to the later Pliocene period, and in this view both Lindgren² and Lawson³ have acquiesced. With these river channels may be correlated the Tulare deposits of the Great valley, while the development of the great Sierran penepplain most writers consider to have taken place later.

The Pleistocene Deposits.—The deposits of the Pleistocene consist for the most part of alluvial fills or other superficial deposits of boulders, gravels, and sands. These deposits are especially abundant at the southern end of the Great valley, where they have been noted by Whitney,⁴ who mentions also the terraces about the Tejon ranch, though he does not designate them as such. The gravel and boulder deposits of the San Emidio canyon he also describes in part, and illustrates them by a sectional profile clearly showing their unconformable relation to the Tertiary formations and to the base-leveling of the adjacent foothills. In the neighborhood of the Midway oil district is a comparatively wide plain to the west of Buena Vista lake at an elevation of 600 feet above the valley, which is largely the product of alluvial filling and base-leveling of the surrounding Tertiary hills. The same class of facts is observable at McKittrick, Temblor, Carisa valley, Cholame, Peachtree, and elsewhere.

These deposits are never clearly stratified and are of the nature of alluvial accumulations on land surfaces, rather than in submerged basins. As in the case of the terraces, they have been considerably obscured by the products of later denudation, and it is not always easy to distinguish the Pleistocene from recent deposits. In many places, as at San Emidio,

¹ Geol. Surv. Calif. Geol. v. 1, p. 250 *et seq.*

² Journ. Geol. v. 4, p. 905.

³ Bull. Dept. Geol. Univ. Calif. v. 1, p. 157.

⁴ Geol. Surv. Calif. Geol. v. 1, pp. 188, 191 *et seq.*

Coalinga, and elsewhere, the Pleistocene peneplains have been extensively dissected by recent stream erosion and their deposits are left covering the mesa-like ridges or hills intervening between stream valleys. In such cases it is not unusual to find unstratified deposits of boulders covering the top of a ridge, or even resting cap-like on the crest of a conical hill. Among the boulders and pebbles of these deposits may be recognized fragments of all the earlier marine deposits of the range including metamorphics, Cretaceous sandstones, Eocene and Miocene limestones, and even many fragments of the immense oysters of the Coalinga beds as well as later fossils.

The fragments of *Ostrea titan* have often proved misleading to prospectors who have regarded them as a guide for the location of oil sands, with which, in their original position, they are often associated.

In those deposits that are most clearly of Pleistocene origin, it is apparent that there is an unconformable relation between them and the underlying formations, and that a period of erosion has intervened. In other words, much of the denudation and base-leveling has antedated the boulder deposits. These deposits are associated with, or more properly include, extensive beds of asphaltum at both McKittrick and Sunset; and in these asphaltum beds have been found the remains of a number of Pleistocene mammals, including the elephant, the horse, and an extinct species of wolf, doubtless representing a fauna belonging to the latter part of the Pleistocene period. It is evident, therefore, that it is to the early or middle epochs of the Pleistocene that the most extensive denudation is due.

STRATIGRAPHIC RELATIONS

As a result of more extended study and closer attention to details it is found to be desirable to revise in some points the stratigraphic classification offered in the preceding paper; although as there stated, the essentials are fairly well shown. Undoubtedly there is evidence of unconformity between the

strata of all of the successive periodic series, and in some cases between different members of the same series.

The unconformity between the Chico and the Eocene is both stratigraphic and faunal when taken throughout their extent, though locally there is often some resemblance between them. But their relations have already been sufficiently well shown. If Oligocene strata are conceded for the Pacific coast, and especially in the formations of the California Coast ranges, then either they should occur in the Mount Diablo range, or their absence should add emphasis to the unconformity between strata of the Eocene and the Miocene. If, however, the Temblor beds are regarded as the lowermost Miocene, the evidence of an unconformity between them and the next older strata is significant, and it is clear that the change from one to the other is too abrupt to be called transitional. The strata immediately preceding the Temblor, however, while they are stratigraphically related to the Eocene in the central part of the range, are faunally and even lithologically like the middle Miocene in other parts of the Coast.

Probably the most noticeable interruption in the sedimentation of the Tertiary is that of the later Miocene—an interruption which intervened between the Monterey and the Coalinga epochs. The evidence of this unconformity is not of the nature of denudation so much as of abrupt change of sedimentation and fauna. This change is conspicuous throughout the range, and in the vicinity of Midway and Sunset shows in the heavy conglomerates, and between Coalinga and New Idria in the thick beds of huge oysters, pectens, and barnacles.

The stratigraphic relations of the Coalinga beds with the succeeding series is not so clear, though evidence is not lacking of some sort of change in the physical geography of the time. In some few places an angular divergence between the Coalinga beds and the Etchegoin has been observed, though this is not the rule. Whatever this change may have been, it was quite sufficient to inaugurate a considerable change of fauna and, on the whole, a noticeable introduction of more recent or modern forms. Two epochs, one marine and the other lacustrine, are postulated for the Pliocene; and while

their strata are mutually conformable and no clear evidence can now be offered to the contrary, it is not impossible that such evidence may be found when the fresh-water series shall become better known.

Deposits of Pleistocene age, in the form of alluvial gravels and other superficial and unstratified accumulations, rest unconformably upon strata of all of the older series, including those of the Tulare, signifying that a long period of denudation intervened between the latter and the late Pleistocene.

CORRELATIONS

The minor provinces or basins of the Pacific Coast Tertiary deposits have not yet been delimited, and the final correlation of strata studied in different parts of the coast region must await a fuller knowledge of geographical conditions. Even within the limits of California, provincial differences are apparent, and there is a liability to error unless a degree of caution is observed; still within limits some correlation is safe and desirable.

In the Salinas valley, Tertiary strata are known which can be satisfactorily compared with those of the Mount Diablo range; but in the Coast ranges to the west of the Salinas, bordering on the open sea, it is quite likely that both sedimentation and biological conditions were different.

Thus far the stratigraphy of the Eocene is only imperfectly known and has been less studied in the outer ranges than in the Mount Diablo range. Dr. Ralph Arnold¹ has given a brief and comprehensive sketch of the Eocene occurrences of the Coast, in which he has endeavored to recognize in each the various subdivisions as thus far described. In its more characteristic and better known portion, namely the Tejon, such an attempt is certain to be more successful and satisfactory than in other portions. The Tejon beds occurring in the Mount Diablo range are correlated with similar occurrences in all parts of the Coast, including Washington, Oregon,

¹ U. S. Geol. Surv. Prof. paper, no. 47, pp. 10-17.

California, and the peninsula of Lower California. Farther than this it is not now desired to follow them, though no doubt enough is now known of them to render it possible to recognize their equivalents in other parts of the United States.

In the same paper Dr. Arnold has mentioned supposed occurrences of Oligocene rocks at various points on the West-coast and has described a formation which he calls the San Lorenzo, which he doubtfully refers to this horizon. The fauna as there described is essentially Eocene, though it contains many species occurring in the lower Miocene as elsewhere known. It is quite likely, though not yet proved, that the Upper Eocene shales of the central Mount Diablo section should be correlated with the San Lorenzo. In the same way they may be correlated with the upper part of the Sespe formation described by Eldridge and Arnold¹ as occurring in the mountains of Ventura county, and tentatively classed as Oligocene.

The horizons of the Miocene can be safely correlated only within narrower limits, and it is not now intended to extend such correlation beyond the immediate environs of the Mount Diablo range.

Homer Hamlin² has described certain beds under the name "Vaquero Sandstone", and Dr. Fairbanks³ and Arnold⁴ have repeatedly employed the same name in various papers. The type locality from which the name is derived, however, lacks thus far any faunal or even stratigraphical description, and as it can not be found on any published or official map of the state or county in which it is said to exist, it is difficult to decide what portion of the Miocene rocks, if indeed any, should be classed under this name. The locality has been loosely defined as the eastern slope of the Santa Lucia range, or the western side of the Salinas valley, etc. Hamlin's description is quite too meager to identify its position in the stratigraphic scale, and aside from suggesting that it is not

¹ U. S. Geol. Surv. Water Sup. & Ir. no. 89, p. 14.

² U. S. Geol. Surv. Bull. no. 309, pp. 10-12.

³ U. S. Geol. Surv. San Luis folio, p. 4 *et seq.*

⁴ Proc. Am. Phil. Soc. v. 43, pp. 19-20; U. S. Geol. Surv. Prof. paper 47, pp. 18-19; U. S. Geol. Surv. Bull. no. 309, pp. 12-17.

the basal member of the Neocene, he does not define its place. In his attempt to describe the fauna of the "Vaquero Sandstone" his materials were taken from a series of sandstones overlying the Stone canyon coal vein on the west slope of the Mount Diablo range. Stratigraphically and faunally it agrees with the Temblor beds, as was determined by the writer before Mr. Hamlin's description appeared.*

Most of the strata that have been described under the name "Vaquero Sandstone", as far as known, represent a well characterized horizon of the Lower Miocene, and as such are without doubt to be correlated with the Temblor beds of the Mount Diablo range.

The Monterey shales occurring in the Middle Miocene of California have generally been called by that name; hence little is to be said regarding their correlation with the same in the Mount Diablo range. In general, however, there is a tendency to trust too far to lithological characters in their identification, and it is not unlikely that error has thus originated more than once in the application of this name.

The San Pablo beds described by Dr. J. C. Merriam as occurring on San Pablo bay, have not yet been sufficiently well exploited to enable a close comparison to be made. The fossils contained in the published lists of the San Pablo bay and Kirker's Pass localities are almost entirely those of the Etchegoin, rather than of the Coalinga. The species which chiefly characterize the lower series do not appear in the San Pablo as at present known, though it is quite possible that a greater resemblance will be found when both become better known. In the San Pablo at its type localities no mention is made of the abundant occurrence of *Pecten*, *Ostrea*, *Tamiosoma*, *Chione*, *Agasoma*, *Volutilithes*, *Chorus*, *Cancellaria*, *Turritella*, etc.

In the former paper the San Pablo, as known from its type localities, was correlated with the Etchegoin; and this seems to be its closest ally among the stratigraphic series farther

* As for the name "Vaquero" and its application to any strata outside of the type locality, it has no logical standing, and its claim upon accepted usage rests only upon assumption.

south, while in the Salinas valley and elsewhere beds that have been generally called San Pablo and otherwise correlated with it, are undoubtedly more closely related to the Coalinga. This is true of the Santa Margarita beds described by Fairbanks,¹ which also occur at La Panza Springs, Nacimiento river, and on the Estrella and San Lorenzo creeks. The type locality of *Ostrea titan*, *Tamiosoma gregaria*, *Pecten estrellanus*, *P. crassicardo*, and many other species described by Conrad, was the Estrella creek where Coalinga beds are abundantly fossiliferous. It yet remains to be shown that these beds are properly correlated with the San Pablo of the type localities, whereas the fauna of the Coalinga beds is unmistakable in them, as in the Santa Margarita beds.

Above the Coalinga beds occurring on the San Juan creek west of the Carisa valley, there are 2000 feet or more of strata, among which the Etchegoin beds and likewise the San Pablo have their place. The equivalents of the Coalinga beds and of the Etchegoin, which doubtless occur in other parts of the Great valley, have not yet been clearly recognized. The classification of the Tulare beds as late Pliocene and their relation to the Merced and Paso Robles formations have already been mentioned. The angle at which the Tulare beds stand in most of their outcrops is evidence of a post-Tulare uplift. It is not unlikely that, when all these formations are better known, it will be found that during the Tulare epoch the Kern-Tulare basin had a more direct relation to the Paso Robles and Merced deposits than that of synchronism.

It would be interesting to trace here the long history of crustal movements as they are illustrated in the Mount Diablo range; but that topic, along with many other interesting features of structure that can not now be taken up, must be reserved for future consideration.

¹ U. S. Geol. Surv. Pub. San Luis folio, no. 101, p. 5-6.